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TOWARD A NONLINEAR THEORY OF WAR:

CHANGING THE ROOT METAPHOR

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TOWARD A NONLINEAR THEORY OF WAR: CHANGING THE ROOT METAPHOR

> It is proposed to show that there is one great principle underlying all the operations of war,--a principle which must be followed in all good combinations   with few exceptions, the most brilliant successes and the greatest reverses resulted from an adherence to this principle in the one case, and from a neglect of it in the other [1]
>
> *- Baron Antoine Henri Jomini,* **The Art of War**

> Efforts were   made to equip the conduct of war with principles, rules, or even systems   This did present a positive goal, but people failed to take adequate account of the endless complexities involved   The conduct of war branches out in almost all directions and has no definitive limits [2]
>
> *- Carl von Clausewitz*, **On War**

> If there can be such a thing as a joke in military history, surely a small one is the belief that with the posthumous publication of Clausewitz in the 1830s, *On War* became the bible of the Prussian army, the source of their great victories of 1866 and 1870, and soon thereafter the chief military theory of the Western world [3]
>
> *- John Shy*, "Jomini," in **Makers of Modern Strategy**

The beginning of the 19th Century was a time of profound upheaval   The French Revolution unleashed the power of a "people numerous and armed" upon the nations of Europe   Napoleon harnessed that power to the nascent Scientific, Industrial, and Agricultural Revolutions and created a new mode of warfare   During and immediately after the Napoleonic Wars, political and military thinkers of all nations and positions faced the challenge of understanding and adapting to Napoleon's methods   Out of the ranks emerged two seminal thinkers whose theories remain influential almost 200 years later – Antoine Henri Jomini and Carl von Clausewitz   As the quotes above illustrate, they approached the analysis of military success from strikingly different frames of reference   And it is an irony of history that while Clausewitz's work is still studied

almost universally, it is the mostly-ignored Jomini who's influence, while quite subtle, is more pervasive Jomini essentially won the battle for posterity because his frame of reference, and thus his methodology and conclusions, was more attuned to the mode of thinking dominant in both his time and the present

Jominian formulations such as "principles of war" and "mass upon the decisive point" have dominated military thinking in general because they fit the framework of the dominant, or root metaphor of Western thinking. In strict terms, a metaphor is "the application of a word or phrase to an object or concept it does not literally denote, in order to suggest comparison with another object or concept "[4] A root metaphor is such a comparison which provides the foundation for an entire philosophy or school of thought The root metaphor of Western thinking is linear reductionism – the assumption that outcomes follow proportionally from inputs and the scientific method of understanding complex systems or problems by breaking them into their component parts Linearity has served for over 250 years as the root metaphor because of its apparent power to explain the workings of the world Jomini tapped into that apparent power when he applied the linear reductionist methodology to the analysis of warfare He emphasized the known or knowable as the key Thus, victory was no longer a mysterious accident or the product of unfathomable genius Rather, it resulted from the correct application of simple principles discernible when one analyzed warfare "scientifically " There was, however, always a recognition that some aspects of human experience, including some aspects of warfare, were not knowable or amenable to scientific analysis – that there were, in fact, nonlinear aspects that could not be explained using the linear metaphor

Clausewitz is the theorist who captured the essence of those uncertainties In contrast to Jomini, he emphasized the effects of chance in warfare His magnum opus, *On War*, is filled with the recognition of what today we call nonlinearities – the capacity of the actions of the most insignificant individual to lead to significant results, and the inability to understand events completely or predict outcomes accurately Today, new, nonlinear sciences[5] are finally opening a window of understanding on these nonlinear aspects of warfare, as well as other arenas of human endeavor A number of scientists, mathematicians, and theoreticians have taken the first steps in applying nonlinearity toward an improved understanding of war This work has proceeded for the past ten to fifteen years, but has generally been applied in discrete topic areas such as modeling or simulations

The nonlinear sciences are proving to be quite useful in these arenas, but their true power lies in their potential to broaden our entire basis for understanding the nature of war Clausewitz's intuitions provide a firm foundation, and the nonlinear sciences provide a means to extend his intuition into the present and expand upon it – perhaps ultimately to create a "neo-Clausewitzian" nonlinear theory of war This paper examines the linear metaphor which has guided Western military thinking and compares it to the inherent nonlinearities of warfare in all its dimensions It thus makes the case for discarding the linear metaphor in favor of a new root metaphor of nonlinearity These thoughts are intended as a first step toward that ultimate goal of a nonlinear theory of war

The Root Metaphor

The idea of metaphor is far richer than connoted by a simple definition Metaphors are a conceptually powerful means of thought which provide implicit structure to much of human reality.[6] We budget time, and analyze the time-value of money, we picture highways as arteries of commerce, and arteries as highways for the body's nutrients, the movements of the solar system become the workings of a giant clockwork machine, and the movements of sub-atomic particles are visualized as planets in a tiny solar system "Metaphor constitutes a ubiquitous, irreducibly complex aspect of any natural language .Metaphors are imbedded throughout our speech patterns [They are powerful] "indicators of networks of meaning "[7] People would be hard-pressed to communicate without using metaphors, and there are different levels of metaphor use The level applicable to this discussion is metaphor as a unitary view – "a symbolic relation that unites the paradigmatic way of viewing an entire field of knowledge," often represented by a particular term [8] In this paper, the label "root metaphor" indicates this type of unitary view

Linearity is the unitary view, the root metaphor, of Western thinking It is ubiquitous in our visualization of the way the world works As Foreign Service Officer Steven Mann notes, "Humans have a terrific need for stability and one of the ways we serve this need is through the search for paradigms We consider reality tamed if we find a classification, a description for it "[9] We have created stability and understanding through the metaphor of the world as a giant, clockwork machine governed by linear relationships

<u>Linearity as Metaphor</u>

To categorize a system or a relationship as linear is to imply two conditions The first is that changes in system input result in <u>proportional</u> changes in system output In other words, small changes in outcome are the result of small changes in input; and similarly, large changes in inputs result in large changes in outcomes This means that linear systems tend to be stable, because relatively small changes in input will not cause the systems to go "out of control" Finally, it also means that exact knowledge of inputs leads to exact knowledge of outputs The second condition of linearity is that of additivity – simply put, the whole equals the sum of its parts Therefore, understanding of the system, or a problem, is gained by breaking it into its individual parts, analyzing the parts, and then reassembling the whole In other words, two plus two <u>always</u> equals four, and this is true because one plus one plus one plus one equals four In order to understand and, more importantly, control the system, we keep breaking it down until we find parts that are basic enough to understand and control – at which point we can understand and control the reassembled intermediate parts, and then the whole [10]

The power of the linear metaphor is the power of explanation The Scientific Revolution seemingly created the capability to understand the world – by breaking larger entities into constituent parts and analyzing the (assumed) linear interactions between them, scientists could predict the outcome of those interactions Indeed, the very definition of science came to mean this method of understanding the whole by understanding its parts, and the epitome of understanding was <u>scientific</u> understanding The natural outcome was an attempt to gain scientific understanding in all fields of study, including the social sciences [11]

This view of science as understanding can be traced back at least to Nicolas Copernicus (1473-1543), who proved the planets revolve around the sun Copernicus is significant not because of his linear thinking, but because he represents the beginning of the separation of reason and science from faith In the medieval world, knowledge of the world was combined with faith in God's control over it Scientific observation and mathematical rigor began to change that world view. In spite of persecution by the Church, Galileo Galilei (1564-1642) formulated laws of nature, in contrast to laws of God, after careful scientific experiments, using the language of mathematics Francis Bacon (1561-1626) extended Galileo's empirical method. His objective was not merely to understand, but to control nature as a servant of mankind Rene Descartes (1596-1650), building on the understanding generated by Copernicus, Galileo, Bacon, and others, created the modern scientific reductionist method He viewed the world mechanistically – a giant machine amenable to understanding through understanding of its constituent parts, the parts to be understood through observation and described in the language of mathematics – and the whole amenable to accumulation of perfect, scientific knowledge Descartes created the conceptual framework and Isaac Newton (1642-1727) completed the metaphor by proving the existence of the giant machine Newtonian physics synthesized the scientific work which had preceded it into one system of understanding with the apparent power to explain the realities of the human world [12] What a powerful idea – a stable, clockwork universe which humans have the power to understand and control

The root metaphor of linearity leads to a number of assumptions regarding the nature of systems Linear systems are assumed to be self-contained, or closed A closed

system is isolated from external influences, contains a finite number of variables, and thereby is stable and can be made highly efficient A second assumption regarding linear systems is that of predictability, which in turn, implies controllability The predictability rests on known rules of operation or behavior If the rules of operation are known, then knowledge of the present condition of the system can lead to knowledge of the condition of the system at any prior or future point in time Knowledge of the rules of operation also implies that the status of the system can be calculated based upon a limited amount of initial information. These assumptions lead to a view of systems as stable, where change occurs in an orderly manner, and where one avoids surprise by accumulating knowledge about the system [13]

The pervasiveness of the linear metaphor is nowhere more apparent than in the use of language – where the stable and orderly are regarded as the norm, and conditions other than the stable and orderly are indicated by negation – nonlinear, asynchronous, irregular, aperiodic, arrhythmic, etc Additionally, the machine analogy predominates, especially when describing positive outcomes – the "well-oiled machine" "fires on all cylinders" and "operates like clockwork" when "all the gears are meshed "[14]

Linearity and Military Thought

The metaphor of linearity is as pervasive in military thought as it is in any other profession The representative writer in this regard is Baron Antoine Henri Jomini, who in some ways did for military science what Newton had done for science in general Jomini, writing at the height of the scientific revolution and after the upheavals of the French Revolution and Napoleonic wars, seemingly brought order and understanding out of the chaos of those events His analysis rested on the scientific methodology of Newton

– warfare could be understood as the sum of its constituent parts and victory resulted from the application of immutable scientific principles The appeal of such thinking was immense If there was a scientific body of military knowledge, then the nascent military professionals (as opposed to the traditional aristocratic officer corps) could justify their existence as a profession, and if there were scientific principles, then victory was assured for those who applied them with greatest effect Although modern military professionals have de-emphasized to a certain extent the direct link between application of principles and potential victory, the scientific, linear mode of thinking about warfare has carried forward to the present [15]

The ubiquity of technology, the extent of military specialization, and the sheer pace of operations all tend to reinforce the linear metaphor at the foundation of military thinking The reliance upon machines (tanks, aircraft, ships – weapon systems) to conduct military operations significantly contributes to a "machine view" of warfare Weapons have known effects, and combinations of weapons have greater effects, and precision weapons have precise effects Military officers are specialists in the management of weapons and weapon effects The pace of operations produces layers of controls, achieved by applying more and more technology in the quest for perfect results

The language and activity of military operations are filled with linearity Planning for military action is a step-by-step process which results in operations plans divided into neat phases of execution Alternative possibilities are accounted for through branches and sequels to the plans Progress is measured by relative position on a map, numbers of enemy killed and captured, number of ships sunk and sorties flown, etc The precise control of operations becomes the means of defeating the enemy, and precise

knowledge results in a greater possibility of victory An air tasking order of hundreds of pages carefully delineates the activity of every aircraft from time of take-off, through air refueling control time and time over target, to time of landing – and includes weapons loads and exact aim points The control of individual units toward a common mission is assured during the planning process through use of synchronization matrices, and during mission execution by control measures and unit boundaries on maps, and through layers of command and control elements connected by extensive voice and data communications links Thus, the pieces of each operation are precisely assembled into a carefully calculated whole

The Root Metaphor and the Real (Nonlinear) World

Regardless of the appeal of the linear metaphor, the "real world" exhibits significant <u>non</u>linearities – instances where things do not operate in a clockwork manner, systems that are open to outside influences, that are unstable, inefficient, unpredictable, and not controllable; systems in which it is impossible to understand the rules of operation or behavior, in which small changes in input may result in large changes in output, in which no amount of knowledge of initial or current states will allow calculation of subsequent or final states

Until recently, scientists have been ill-equipped to cope with nonlinear realities The response has sometimes been simply to ignore them because nonlinear problems are too hard to solve – especially mathematically The difficulty of solution also led some to regard them as worthy of study, but not amenable to true (meaning scientific) understanding But the most frequent approach to nonlinear problems has been to convert them to linear problems – to treat one variable at a time, holding all others constant, or to simplify through creative assumptions (for example – assuming friction to be zero or a straight line function)

<u>Nonlinearity and Military Thought</u>

Military thinkers have taken a similar approach However, even while studying and using simplified prescriptions, military leaders have always been uncomfortably aware of factors which do not easily fit into a framework of principles and prescriptions These factors are usually subsumed under Clausewitz's labels of " fog and friction," or are sometimes labeled "moral factors " In reality, these are the factors which make war a profoundly nonlinear enterprise

The theorist Carl von Clausewitz, although not using the language of nonlinearity, was clear about its effects One of the hallmarks of linearity is proportionality between the inputs and outputs of a system. Clausewitz understood that in war "countless minor incidents . combine to lower the general level of performance, so that one always falls far short of the intended goal."[16] In other words, outputs are <u>not</u> proportional to inputs Clausewitz identified the sources of this lowered performance as danger, physical effort, intelligence errors, friction, and chance, which combine to create a general atmosphere in which each individual retains the ability to frustrate the intent of the commander [17]

Two contemporary authors have taken Clausewitz's insights and placed them in the context of nonlinear science Historian Alan Beyerchen, in an article titled "Clausewitz, Nonlinearity, and the Unpredictability of War," noted that Clausewitz was not a "chaos scientist" before his time, but had an intuitive understanding of unpredictability and complexity, and was willing to incorporate the resulting ambiguities into his theory Clausewitz understood that unpredictability and complexity resulted from the very nature of war In war, there must be at least two sides which react to one another These actions and reactions form a system of dynamic feedback which cannot be construed as merely additive and which depends on context in both conduct and outcome Beyerchen says "The ends-means relationship clearly does not work in a linear fashion The constant interplay is an interactive, feedback process that constitutes an intrinsic feature of war the conduct of any war affects its character, and its altered character feeds back into the political ends that guided its conduct "[18] This iterative feedback process is a hallmark of nonlinear systems

Similarly, in *Clausewitzian Friction and Future War*, military analyst Barry Watts examines in detail Clausewitz's concept of general friction He shows that war has been demonstrated to be a nonlinear activity on both an intuitive level and in simple mathematical models He concludes that "the interaction of iterative feedback can so magnify the smallest of differences, including those stemming from human decisions, as to render combat outcomes *structurally* unpredictable" – that is, no amount of detail or information could ever render the results completely predictable Consequently, the effects of friction cannot be eliminated or even significantly reduced [19]

Trapped in the Linear Metaphor

The nature of the differences between a linear concept of war and the realities of its nonlinearity constitute a trap for military thinkers The trap is of their own making, because they have failed to think thoroughly and rigorously about the "marriage" of the linear and nonlinear in war For those trained toward rigorous linear thinking, three drivers make the trap almost inevitable They are first, a tendency to separate the linear from the nonlinear aspects of war, second, the overwhelming influence of technology, and third, the nature of modern limited war

US military thinkers have drifted toward an analytical separation between the linear and nonlinear aspects of war This action is natural for linear thinkers – to break the whole into its component parts to understand it The "scientific" or linear aspects of war are regarded as givens which can be reduced to hard, knowable facts, while the nonlinear aspects (the "art" of war) are viewed as worthy of study toward a more or less intuitive understanding The trap lies in this separation of the two – sometimes explicit,

but more often implicit – because the nature of nonlinearity insures that there is no truly linear side to war

The implicit separation of linear and nonlinear is best viewed by analyzing conceptual documents such as *Joint Vision 2010* and the *Concept for Future Joint Operations* These documents are important because they guide future thinking in the US military, therefore, they will set the tone for concepts of future warfare They are also typical of military documents, including formal doctrine, in their separation of the linear and nonlinear aspects of war

As noted, this separation is implicit – it is done without conscious intent The continuing effects of fog and friction (the effects of nonlinearity) are acknowledged, but without any depth of analysis or discussion of how they will effect the new concepts put forth. In thirty-four pages, *Joint Vision 2010* contains three references to the continuing presence of fog and friction in war, and one to using improved technology to reduce friction [20] In contrast, the pamphlet is filled with references to technological improvements and perhaps the single word used most often is "precision " The purpose of the document is to provide "the conceptual template for how America's Armed Forces will channel the vitality and innovation of our people and leverage technological opportunities to achieve new levels of effectiveness in joint warfighting "[21] If the nonlinear aspects of war are indeed structural components, one might hope for more than four isolated references to those nonlinearities in the conceptual template of the future

The *Concept for Future Joint Operations*, which is a follow-on to *Joint Vision 2010*, provides guidance on converting that conceptual framework to actual operational concepts The separation of the linear and nonlinear continues throughout this document

as well The pattern established early on is one of acknowledging fog, friction, or "the human dimension" at the introduction or conclusion of a chapter But there is little evidence that these nonlinear concepts are incorporated with any depth at any point in the document [22] In fact, the human dimension is treated separately with one paragraph on physiological considerations, two on psychological considerations, and three on leadership [23] And, a discussion of "culmination" concludes that it is unlikely to occur on the future battlefield, thus ignoring completely the potential for individuals, such as key commanders, to reach their culminating points [24]

Further, one of the chief sources of nonlinearity in warfare, the enemy, is for the most part treated superficially in both documents – most often as a target, or as being in the position of merely reacting Chapter seven of the *Concept for Future Joint Operations* contains the only explicit acknowledgement that the enemy helps determine the outcome of the conflict and is not always predictable [25]

This unthinking separation of the nonlinear from the linear makes it easy for military thinkers to disregard the true effects of nonlinearity An examination of one military writer who makes explicit this separation serves to illustrate even more starkly the dangers and fallacies of such a view Colonel John Warden, USAF (ret), who led the strategic design of the Gulf War air campaign, has created a framework which clearly separates the linear (what he terms the "physical") aspects of war from the nonlinear

Colonel Warden says we "must demystify war,"[26] which he explains by asserting that the Napoleonic/Clausewitzian formulations of fog, friction, and the importance of morale are no longer valid He goes on to say that morale, fog, and friction have not disappeared, but that "we can now put them in a distinct category, separate from the

physical we can think broadly about war in the form of an equation (physical) x (morale) = outcome "[27] This relationship holds true, he says, because individual fighters are now dependent on physical things and technology, without which they cannot affect the enemy As a result, "the physical side of the enemy is, in theory, perfectly knowable and predictable ..the morale side is beyond the realm of the predictable Our war efforts, therefore, should be directed primarily at the physical side " He further asserts that "the advent of airpower and accurate weapons has made it possible to destroy the physical side of the enemy "[28] Thus, if you destroy the physical side, you achieve victory without the necessity of coping with the unknowable, nonlinear aspects of war

Warden's extreme view makes clear the appeal of separating the linear and nonlinear If such a separation is possible, then war is susceptible to scientific analysis and understanding, and victory is predicated upon superiority in weapons The idea that the linear aspects of war are knowable exerts an irresistibly seductive effect and makes this notion the most powerful of the three drivers toward linear thinking

The second of the three is the importance of technology in modern warfare and the nature of its influence That influence takes two distinct forms, seemingly opposite in nature, but both driving military thinkers toward linearity Throughout history, technology has served as a means of increasing the lethality of warfare, to the point that nuclear weapons provided the capability to kill millions of people indiscriminately with a handful of "bullets " Today, that quest for lethality has become, rather than a quest to kill more of the enemy, a quest to "kill" his ability to act as a coherent military force – by removing the ability of leaders to control their forces, by creating a pace of operations which outstrips the enemy's ability to react, and by subjecting his troops to a whirlwind

of action that physically and psychologically dislocates them In *Coping with the Bounds, Speculations on Nonlinearity in Military Affairs*, National Defense University faculty member Tom Czerwinski has claimed that such "overwhelming force can significantly linearize conflict "[29] In effect, it is assumed the lethal technology eliminates, or reduces significantly, the nonlinear aspects of war – at least on the winning side

At the same time, however, advances in military technology have created an almost completely opposite trend which also produces linear thinking about warfare In addition to creating "overwhelming" force, military technology has become focused, to a large degree, on the ever-more precise identification of targets and delivery of weapons to achieve precise ends with limited means, while limiting casualties and collateral damage Inherent in this conceptualization is linear thinking regarding weapons as inputs and effects as outputs in a grand scheme of military action as calculus

This emphasis on precision also helps illustrate the third driver toward nonlinear thinking – the nature of modern limited war. Modern warfare, especially as the United States has chosen to conduct it recently, is limited to a significant degree These limitations have included limits on ends, ways, and means Limited war leads to an emphasis on the linear side of warfare because the very idea of limits implies measurability and control – control over inputs, outcomes, battles and engagements, weapons, and ultimately, control over one's enemy without the need for total destruction Implicit in the need for control is the need for a high degree of rationality, and thus linearity, on the part of both sides in the conflict

The ultimate reality, however, is that the separation of the linear and the nonlinear is a false dichotomy – and is, essentially, impossible As Professor James Rosenau asserts, "human affairs have both linear and nonlinear dimensions, and while there is a range of conditions in which the latter dimensions are inoperative , <u>it is not known when or where the nonlinear dimensions will appear and trigger inexplicable feedback mechanisms</u> [30] (emphasis added) In the realm of combat, there is an essential "nature of war" that is not divisible into its constituent systems Combat is a quintessential example of a human activity greater than the sum of its parts, and war ceases to be war if it is "taken apart " Thus, although it might be acceptable for a beginning student of military theory to "simplify the equation" (i e focus only on the linear), that student should never conclude that the conduct of war can occur only in a linear realm After all, in a linear world, the underdog never wins [31]

Changing the Root Metaphor

The linear metaphor limits understanding, leads to weaknesses in theory and doctrine, and constrains the ability to formulate credible visions of the future Yet linearity persists, not only because of its inherent appeal, but because until recently, there was no alternative view Now, however, advances in the computational capabilities of digital computers have given scientists and mathematicians the opportunity to actually solve nonlinear problems for the first time This ability has led to entirely new fields of study – chaos, nonlinear dynamics, complexity, complex adaptive systems, cellular automata, artificial life, etc More importantly, these new fields of study have made explicit the pervasiveness of the root, linear metaphor and the fundamental inadequacy of such a linear view of the world That fundamental inadequacy means the root metaphor must change The new root metaphor for military thinkers must rest on a foundation of nonlinearity – and the nonlinear fields of study most applicable to military theory are complexity and complex (adaptive) systems

Complexity Theory

Although nonlinearity is the mathematical fact underlying the new sciences, complexity and complex systems are not amenable to concise definition Indeed, one researcher has compiled a list of three dozen ways scientists use the term "complexity " From another perspective, Nobel physicist Dr Phillip Anderson has summarized the concept as "more is different "[32] There are, however, ideas between these two extremes which are useful for the task of changing the root metaphor and achieving a more accurate foundation for military theory

At the core of complexity theory are complex adaptive systems A system has two defining characteristics First, individual elements are connected such that changes in one or more elements or their relationships to each other (i e , their connections) result in changes to other elements Second, the collection of elements as a whole exhibits characteristics (properties and behavior) different from those of the individual components We, therefore, cannot understand systems merely by breaking them into their parts nor can we analyze interactions by merely looking at pairs of parts [33]

Systems, in general, often display nonlinear dynamics, therefore, the results of actions often cannot be predicted and outcomes are sometimes less or more than the sum of inputs Small inputs may have great effect, but, similar to the economic law of diminishing returns, more may not result in even greater effects Conversely, input may have little effect until some "critical mass" is reached Also, an input may have no effect unless some other input or condition is present Finally, "in a system, the chains of consequences extend over time and many areas the effects of action are always multiple 'we can never do merely one thing' "[34]

In complex adaptive systems

> the interrelationships of the agents is what makes them a system The capacity of the agents to break with routines and thus initiate unfamiliar feedback processes is what makes the system complex The capacity of the agents to cope collectively with the new challenges is what makes them adaptive systems [35] [emphasis added]

Given the existence of complex adaptive systems as a foundation, there are four key premises of complexity theory The first is self-organization and emergent properties As agents of a complex adaptive system build relationships with each other, they form recurring patterns of behavior which form an orderly whole As this process

occurs, new properties or attributes appear For example, when the human brain exhibits intelligence, it is also exhibiting self-organization and emergence The individual characteristics of the components of the brain (neurons, dendrites, neurochemical transmitters) do not account for the existence of intelligence Yet, as the brain grows and matures, the components organize themselves so as to be able to control the functions of the human body, and the quality of intelligence emerges from that self-organized, complex system The second premise is the existence of adaptation and co-evolution Complex adaptive systems have the ability to maintain essential elements of structure within acceptable limits (i e they are recognizable as the same system) by maintaining a balance between external demands and internal needs At the same time, they change in response to their environment, just as the environment changes in response to the system This evolutionary march is not a linear progression. Periods of stasis or infinitesimal changes are marked by sudden "lurches" or extreme change – a phenomenon labeled "punctuated equilibrium " The third key premise rests on the power of small events As Rosenau explains – "Small, seemingly minor events can give rise to large outcomes, systems are sensitive at any moment in time to the conditions prevailing at that moment and can thus initiate processes of change that are substantial and dramatic "[36] The classic historical example of this concept is the assassination of the Archduke Ferdinand in 1914 which started the chain of events leading to World War I The final premise is that of sensitivity to initial conditions – which means "even the slightest changes in initial conditions can lead to very different outcomes "[37] This notion does not mean those different outcomes are always bad Again, a classic example is the possible course of events if the millions of casualties of World War I had included Adolph Hitler.[38]

These characteristics of complex systems can also be summarized in a slightly different manner The ultimate meaning of complexity consists of two related, but not necessarily interchangeable, concepts, neither of which is easily quantifiable The first is system complexity – focused on structure or organization The actual configuration of the components of the brain or the constantly shifting arrangements of the molecules in a fluid are examples The second is behavioral complexity – focused on the actual activities of systems as they evolve An example is the so-called "butterfly effect," whereby weather patterns are altered by a butterfly flapping its wings at some point on the globe [39] Both concepts are necessary when describing complex adaptive systems

Complexity and Warfare

An appreciation for and knowledge of complexity and complex adaptive systems provide a means of understanding the nonlinearities of warfare Such an understanding allows us to study military operations holistically rather than through an unproductive separation between the linear and the nonlinear As Clausewitz reflected

> The strategic elements that effect the use of engagements may be classified into various types It would however be disastrous to try to develop our understanding of strategy by analyzing these factors in isolation, since they are usually interconnected in each military action in manifold and intricate ways we shall continue to examine the picture as a whole the idea we wish to convey will always have its origins in the impressions made by the sum total of the phenomena of war [40]

A modern day systems-cum-military theorist could not have stated the case for the application of complexity theory to military thought any better

Theory serves as a guide to learning and a means of training one's judgment It is meant not only to educate the mind, but as a guide to self-education [41] To begin the move toward changing the root metaphor and developing a nonlinear theory of warfare, it

is instructive to compare what we know about war, armies, and military operations to the above descriptions of complexity and complex adaptive systems Three general observations hold

Observation One. The military world exhibits both system complexity and behavioral complexity In spite of neatly hierarchical "wiring diagrams" and chains of command, the structure and organization of warfare are complex The military instrument of national power is connected to and used in conjunction with other instruments Politics and policy decisions intrude upon "purely military" considerations Modern combined arms warfare, joint operations, and the contributions of coalition partners and allies result in a constant shifting and reforming as operations are completed, missions are accomplished, and depleted units are replaced or reconstituted

The behavior of military systems is perhaps even more complex than their structure and organization Differences in training, doctrine, and equipment lead to differences in competency with differences in mission Differences between services lead to differing interpretations of political direction and differing views on the best means of accomplishing a specified mission Unit and individual morale is influenced by training, fitness, lack of sleep or food, winning and losing – and can have a salutary or deleterious effect on relative strength in numbers or weapons technology

Observation Two The four key premises of complexity theory also apply to an understanding of wars, armies, and military operations Military units and operations, by design, lead to self-organization and emergent properties Even when "no plan survives first contact with the enemy," the chaos of individual engagements and battles resolves into self-organized activity toward a designated mission objective – albeit with varying

degrees of success Leadership is arranged in a hierarchy so that if one leader is lost, another is ready to step into place Units are trained to maintain cohesion and mission focus in spite of losing contact with higher headquarters or adjacent units Combined arms warfare relies upon the emergent synergy between infantry, armor, artillery, and air in creating an outcome greater than the sum of the parts [42] Emergence is also evident in warfare in that tactical events determine outcomes at the operational and strategic levels, but those outcomes cannot be predicted based on outcomes of individual tactical engagements or as the sum of several tactical engagements Strategic and operational outcomes, in turn, feedback into tactical engagements [43]

Secondly, military units and operations, again by design, are subject to adaptation and co-evolution The essential elements of structure remain recognizable as service units are task-organized and joint task forces are formed in response to mission requirements Individual units are formed and reformed in response to engagements, battles, and casualties The battle space (i e the environment) changes as a result of military activity, and military systems change as a result of changes in the battle space For example, early in a conflict an aerial strike force may contain significant resources devoted to suppression of enemy air defenses As air defenses are destroyed, later strike packages need significantly lesser amounts of those resources Military operations are also susceptible to punctuated equilibrium where long periods of stalemate succumb to sudden breakthroughs and periods of rapid movement

Thirdly, military units and operations are notably sensitive to the influence of small events – a key leader who is reassigned, the platoon attack that stops at the wrong time, the cruise missile that hits the wrong target, the cancellation of orders that arrives

five minutes too late, the change in orders that reaches the primary unit but not the supporting unit All these seemingly small incidents can have effects out of all proportion to the individual occurrences

Finally, military units and operations are also notably sensitive to initial conditions – for example, the choice of assumptions upon which to base a plan, the loss of one key leader an hour before a scheduled attack, the choice of an axis of advance, or the accuracy of knowledge of enemy dispositions

Observation Three A sophisticated understanding of nonlinear systems and systems theory is necessary to the understanding of both friendly and enemy actions, and the outcomes of their interactions This necessity is most apparent when systems theory is applied to targeting and target analysis A knowledge of complex systems is vitally important to US military leaders because of the nature of recent US military action which is characterized by limited objectives, constraints on action, and precision strikes aimed at achieving precise effects

A hypothetical example will serve to illustrate the pitfalls of linear analysis of systems Suppose the US is conducting a limited military campaign against a "rogue state " Target analysis indicates that a particular electrical power station provides power to several key enemy military installations, including a national-level command and control node The analysis also indicates that the station provides power to a major civilian hospital with the country's only intensive care unit for children However, human intelligence sources have provided incontrovertible proof that the hospital is equipped with a state-of-the-art backup generator which is tested regularly Based on these facts, military planners recommend that the power station be targeted and the

commander orders it destroyed The strike takes place as planned and is a complete success, the command and control node and other military installations "go off-line" with an absolute minimum of collateral damage Within an hour, however, CNN is broadcasting live from the hospital where a number of children have died and more deaths are expected since there is no power to the life support systems – the backup generator failed to operate The target nation denounces the US action as "barbarous," Third World countries are unanimous in their condemnation, and even staunch US allies fail to defend the action US policy is dealt a crippling blow

This simplistic example illustrates how a shift from a linear, reductionist analysis to a nonlinear analysis focused on systems complexity can yield a subtly more powerful conclusion The linear chain of reasoning is based on what is <u>known</u> – destruction of the power station will cause harm to military targets, the hospital has a backup generator Nonlinear reasoning leads to an appreciation for what is <u>unknown and unknowable</u> – the generator may be out of fuel, the switch that trips it on may not operate, an internal component may fail. The decision to strike may remain the same, but if planners and decision makers recognize what they cannot know, they should be better equipped to cope with the inevitable unforeseen consequences of their actions In this case, recognizing that they cannot know whether the generator will work may lead decision makers to an assessment of the potential "costs" of its failure As a consequence, they might prepare a public affairs "damage control" plan to assuage the effects, or they might be able to assess the potential reaction of friends and allies ahead of time Ultimately, they might cancel the strike or choose to strike a different target

The lessons depicted in the example are confirmed by Steven Rinaldi, an Air Force officer who has studied the implications of complexity theory for strategic targeting, particularly as practiced by the USAF. Rinaldi claims that "targeting has largely been reductionist" (i e , linear) throughout history, but finds a pattern of evolution toward a greater appreciation of complexity He confirms that the power of complexity theory lies in an understanding of systems theory and the interconnections between complex systems [44] Knowledge regarding the nonlinear nature of those interconnections results in decision makers understanding that limited attack may lead to unintended and cascading effects, that, conversely, all-out attack may yield limited results, and that the ultimate effects of precise attacks are never completely precise because of the unknown and unknowable factors inherent in the enemy system

Complexity and the Multi-Dimensionality of War

Given the above description of the basic relationship between complexity and warfare, a more detailed analysis is possible A useful construct has been proposed by historian and Army officer, Antulio Echevarria According to Echevarria, war is conducted in the following dimensions political, social, technological, logistical, informational, operational, force (lethality and violence), and organizational [45] All of these dimensions exhibit nonlinearity and complex interactivity, and in various contexts exert varying degrees of influence on the totality of war Examination of the nonlinearity/complexity exhibited within each dimension will contribute greatly toward understanding the need to change the root metaphor and develop a nonlinear theory of war

The Political Dimension "The political dimension consists of political aims and politics as a process."[46] In the overall formulation of strategy, the link between ends and means is nonlinear. It is nonlinear because of the difficulty in identifying national interests, formulating overall political objectives, and then military strategy and objectives Thus, in the long run, military action may or may not serve the political interest toward which it is directed A further nonlinear factor is the inability to predict or anticipate the political outcomes of military events This fact is especially true in a limited conflict where an attempt to achieve limited ends by limiting the means is often stymied by the nonlinear relationship between them – not to mention the nonlinear interaction with the enemy The use of military force by the United States in the former Yugoslavia perfectly illustrates the nonlinearity of this dimension

In a broader context, a security dilemma often results from the circular effects of complex political interactions A state seeks to increase its own security to prepare for an uncertain future, but in so doing, decreases the security of neighboring states – which respond by seeking to increase their own security, thus decreasing the security of the first state, and so on The cycle continues until some breaking point is reached – often a war We can see such a circular interaction taking place with the Japanese prior to World War II[47] and more recently with the Soviet Union, where the break point was economic collapse rather than war

The Social Dimension The social dimension of war accounts for the influence of the people – their overall attitude and commitment to military action Regardless of the form of government, the people of the state are important because they are necessary to support the size and cost of large, technologically dependent standing military forces, and

because the sophistication of mass politics has made them an emergent phenomenon with the potential of degrading or aiding military action by orders of magnitude [48] Because this dimension consists solely of human interactions, it is profoundly nonlinear and exhibits great complexity For example, the percentage of the US population which actively opposed the war in Vietnam through violent protest was quite small when compared to the "silent majority," and the protesters had a significant influence on US policy decisions and the eventual end of the war But, it is a fact that even after the height of the protests in 1968, it took another five years for the war to end So the question of how and to what degree the opposition influenced the outcome is not amenable to linear analysis or simple conclusions Another example of the nonlinearity of this dimension is the large public outcry and the almost immediate departure of American forces from Somalia after a relatively small number of casualties The public reaction was not based solely on the number of casualties, but also on the perceived lack of clarity in US involvement, the manner of the soldiers' deaths and the public defiling of their bodies, the lack of heavy weapons, and the perceived "over-influence" of the UN on US policy None of these factors is quantifiable nor are they susceptible to simplification or simplistic analysis

The Technological Dimension According to Echevarria, the technological dimension is now pervasive in its influence on all the other dimensions and in all levels of war,[49] and is thus worthy of a more extended discussion It is also a dimension in which the influence of the linear metaphor is subtly pervasive and its most negative effects are largely unrecognized The linear metaphor is most evident in the application

of technology toward the effective elimination of fog and friction and toward the quest for ever-more precise weapons and weapon effects, especially at the strategic level

Although most military thinkers would agree that total elimination of fog and friction is impossible, the discussion in the second section of this paper shows that the depth of analysis and understanding of these factors is lacking, particularly with regard to the effects of technology Eliot Cohen has provided a useful series of observations

He notes that as technology allows an ever-increasing pace of operations, simple time shortages result in increased pressure on planners, decision makers, and executors which, among other possible errors, may lead to misinterpretations – of messages, photos, intercepts, etc Cohen goes on to point out that information gathered and presented electronically is perceived as unambiguous when, in fact, it carries many imbedded ambiguities The technology also sifts and interprets information based on imbedded assumptions which means the information presented is essentially an abstraction of reality Furthermore, the technologies that permit all-weather, 24-hour military operations mean leaders and executors are increasingly affected by fatigue Other effects of technology include an almost inevitable drive toward centralization because rear commanders have the same or even more information than on-scene leaders, the negative implications of training in a "cyberworld" if the real world does not match the training environment, and the creation of scarce, high-tech information gathering machines as the most lucrative targets for a potential enemy [50]

On the surface, the increased use of technology would seem to make warfare more linear, thus validating the old root metaphor Cohen's observations show how technology introduces a significant nonlinear complex component, with greater effects

because they go unrecognized Technology may be the direct cause of nonlinear events such as errors in execution, incorrect assessments of enemy actions, or failures to communicate effectively, instead of the solution to such problems as it is often touted Subtle ambiguities are introduced when analog information is converted to digital "packaging" for transmission and is then re-packaged as graphical interface symbols on a screen – which, to be precise, must be interpreted by a user with the same mindset as the individual who designed it Additionally, any technology is a product of the assumptions of its designers A user who is unschooled in those assumptions may use the technology differently or incorrectly, provide incomplete or improper inputs, or interpret its outputs differently or inaccurately

The lack of validity in the linear metaphor is also evident in the attempt to use technology to achieve precise military outcomes – particularly in the use of precision strikes to achieve strategic effects with less than total destruction of the enemy Again, on the surface linear reasoning appears to hold sway, but a more rigorous analysis points out its failings Strategic analyst Robert Spulak proposes that for precision strikes to result in precise strategic outcomes, five criteria must be met First, there must be some finite number of targets that are in some way critical to the enemy Yet, that number hinges on several complexly related factors – what "level of pain" the enemy leadership is willing to accept, what level it can accept and still function, whether enemy military forces will act even if severed from contact with national leaders, and how one finds the answers to these questions

A second criteria is precise knowledge of target locations. If there are only a few critical targets, then it may be possible to hide, mobilize, harden, or otherwise protect

them, whereas, if there are a large number, then there are probably too many for strategic attack to have the desired effect. As the attempt to target Iraqi Scud missiles and nuclear/chemical/biological facilities during the Gulf War showed, this factor is not a trivial consideration, nor is it merely a matter of precision intelligence

The third criteria is the choice of the number of targets to be engaged. This decision is essentially a function of economics in that the expense and nature of precision weapons drives users toward a "right-sized" stockpile They cannot afford to buy too many, and it is pointless to buy too few The right-sized stockpile leads to the "Goldilocks Dilemma" in application – an enemy must be just right for precision munitions to be strategically sufficient without being unnecessary And there is no way of calculating the right-size before a conflict ensues or even after a specific enemy is identified because of the complexities noted in the first criteria

The fourth criteria is the physical accuracy of the strikes While many factors may lead to degradation of accuracy, an announced strategy of precision strike with minimum collateral damage and casualties leaves one open to charges of terror bombing and/or incompetence if accuracy is degraded to even a small degree

The final criteria involves the effectiveness of the chosen weapon against each target and the ability of the enemy to accommodate whatever damage has been inflicted The attacker's effectiveness is dependent upon absolutely precise knowledge of the target and subsequent actions are dependent upon precise assessment of the damage The attacker almost always overestimates the amount of time and effort an enemy requires to recover – because most complex systems have built-in redundancies, therefore, critical nodes may be critical without being singular Conversely, in an attempt to limit damage

or precisely calibrate it, one encounters the problem of how to calculate this effect ahead of time [51] Spulak's analysis thus clearly shows the inherent nonlinearities of even the most precise weapons

The Logistical Dimension While the nonlinearities of technology are dangerously subtle and largely unrecognized, one might be tempted to regard the nonlinearities of the logistical dimension as so subtle as to be largely irrelevant, or even nonexistent After all, logistics is a matter of almost pure calculation – of amounts of food, fuel, ammunition, and medical supplies – and of the transportation resources necessary for it all to reach the desired location at the desired time And while logisticians know their calculations are merely straight-line approximations, that linear framework has apparently provided an adequate basis for the logistical support of military operations through the years

There are, however, two related factors which make nonlinearities as important in this dimension as in all the others First, those straight-line approximations have always contained a healthy "fudge factor" of extra materiel so as to have enough on hand in the event of unforeseen circumstances The current move toward "lean logistics" which drastically reduces or eliminates the excesses in the military logistics system also makes the system more susceptible to those unforeseen circumstances – whether they originate within the logistical dimension (an airplane carrying critical supplies crashes on take-off from an icy runway) or from one of the other dimensions (operational planners change their minds and shift the main attack axis 200 kilometers to the west)

Secondly, and more importantly, the greatest source of nonlinearity in the logistical dimension is the fact that <u>the ultimate "consumer" of military logistics is the</u>

enemy – who has a vested interest in assuring that the logistics system fails Therefore, the more tightly linear one side makes its logistics system, the more enticing a target it becomes and the more severe the consequences of a successful attack will be

The Information Dimension The informational dimension is also permeated with nonlinearity and complexity – not only related to the way technology presents information, but even more fundamentally, related to the manner in which individuals perceive and use information The information needs of a commander are not only different at different levels (strategic, operational, tactical), but are different for each commander because of differing levels of experience, comfort with ambiguity or lack of information, or types of missions. These differences result in nonlinearity because information requirements are thereby sensitive to initial conditions [52]

Barry Watts offers further relevant observations regarding the nature of nonlinearities in information processing [53] He notes that one of the key purposes of military information systems, the prevention of strategic surprise, is a matter of effective information processing Preventing surprise depends on accurately pinpointing and understanding a signal or signals of what is to come in the midst of competing signals and irrelevant information. Additionally, it depends on taking an appropriate warning from that signal, and then taking action or getting decision makers to take action based on that warning He concludes that surprise is an intractable problem because of "uncertainties and aspects of human perception and judgment too fundamental to eliminate once and for all" and which are "too basic for technological advances to affect "[54]

Watts then makes a second argument for the persistence of informational nonlinearities – based on the inaccessibility of information within complex systems This

inaccessibility is cause by distribution of information across space and time Certain information is available only at certain locations in decision-space (that is, locations in physical space and time appropriate to the decision at hand) and is unsurveyable by those not at that location For example, one usually cannot ascertain the exact nature of an enemy's plans. Similarly, certain information is available only at certain times For example, information on whether the Iraqi Republican Guard was destroyed "enough" in 1991 to eliminate it as a threat was not available until 1994 when the tanks that had escaped were again used to threaten Kuwait [55]

Watts differentiates between tacit and explicit knowledge, which further supports his assertion regarding the inaccessibility of information within complex systems Explicit knowledge is "meaningful information that is available for entry into data and information systems " It is susceptible to the distribution problem described above Tacit knowledge, on the other hand, "encompasses the implicit information and processing capabilities that humans carry around inside them by virtue of their genetic endowment and biological development, cultural background and upbringing, and cumulative individual experiences " An example of tacit knowledge is the ability of a company commander to anticipate the reaction of one of his platoon leaders to an unexpected combat situation based on his knowledge of the individual and their shared previous experiences. This knowledge is inaccessible, or at least not directly accessible, to the system as a whole because it is usually drawn upon only implicitly – often without conscious thought by the individual using it He extends this concept to the organizational level, implying an aggregation of these considerations (i e , development, background, experience, etc) within a unit composed of multiple individuals, with the

aggregation often proving dysfunctional because each factor is different for each individual Watts concludes that the problem of tacit information is also intractable. Thus, the nonlinearities of the informational dimension are permanent because of the existence of dispersed and tacit information [56]

The Dimensions of Force and Operations The operational dimension and the dimension of force are closely related since both deal with the physical application of combat power The nonlinearities of the operational dimension are best summarized by Clausewitz

> War is not an exercise of the will directed at inanimate matter, as is the case with the mechanical arts, or at matter which is animate but passive and yielding, as is the case with the human mind and emotions in the fine arts In war, the will is directed at an animate object that <u>reacts</u> [57]

In other words, the linear metaphor is totally inadequate to describing or understanding the interactions between forces on the field of battle

Echevarria describes the dimension of force as the degree of lethality and violence applied to conflict He regards it as an emerging dimension worthy of independent analysis because of the continuing development of non-lethal weapons [58] The degree of lethality and violence is also closely related to the quest for precision strikes directed toward precise results while carefully limiting casualties and collateral damage This dimension is also permeated with nonlinearity and complexity

The use of non-lethal weapons does not in any way alter the reactive nature of the target of those weapons Thus the dance of action-reaction described by Clausewitz does not change In the realm of precision strike, Cohen has pointed out that force works only if one is willing to use it, and that at some point in the movement toward minimization of

casualties, one loses the ability to instill fear in one's enemy [59] There is also inherent in the idea of limitation the basic premise that victory rests on convincing one's enemy he is beaten rather than actually defeating his forces Conversely, if the cause is regarded as sufficiently important to that enemy, one can be reduced to killing each individual, to the last person [60] Thus, the more the level of violence is reduced, the more complexly nonlinear the conflict becomes

The Organizational Dimension Similar to several of the other dimensions, it would appear on the surface that organization is a straight-forward, linear concept However, this perception is not true – because the function of organization is to provide a means of sharing knowledge to facilitate action that accomplishes a mission This sharing of knowledge is not only subject to the same nonlinearities described in the discussion of the technological and informational dimensions, it has inherent nonlinearities in its own right

The means of sharing organizational knowledge in a military context is command and control, which is both a function and an action – both of which are nonlinear Command and control requirements are information-sensitive and nonlinear because data is highly variable and human intensive Command, therefore, is inherently an act of uncertainty A subordinate commander assumes the role of interpreter[61] – of events and of the intent of higher level commanders, regardless of the level of detail in the organization and the amount of information passed between levels, because there is no way to anticipate all possibilities Each individual retains the capacity to introduce a nonlinear event,[62] and the enemy always retains the capacity to act, unless totally destroyed The organizational dimension also remains nonlinear because of multiple

feedback loops – some created by design, most not, and many unrecognized[63] Finally, organizations are nonlinear by design They exist to increase output exponentially, to insure that output is greater than the sum of inputs If they do not serve this function, they have no reason for being

Implications for Military Theory

The linear metaphor implies predictability and determinism It leads to a quest for ever-greater, more perfect situational awareness, intelligence, and information, thereby meeting the need to reduce fog and friction to an absolute minimum[64] However, this quest is the military equivalent of Don Quixote flailing at the windmills Echevarria, in formulating this construct of the multiple dimensions of war, argues for an "inter-dimensional" approach to military theory[65] This examination of the nonlinearity and complexity which abounds in all the dimensions points to a need to go one step further The analysis brings to light the dynamic, complex interactions within and between all the dimensions Any attempt to linearize, to quantify, or to simplify those interactions is fruitless Even one of those ever-popular social science diagrams in which words or phrases are arranged in overlapping bubbles or are connected by double-headed arrows, each one to all the others, would not do justice to the complexities illustrated here They must be put in a purely mental framework based on an intuitive understanding of those complexities They must be understood in terms of a nonlinear root metaphor

The characteristics of complexity and complex adaptive systems are prevalent throughout all the various dimensions of war Any nonlinear theory of war must, therefore, be based on the following basic lessons of complex systems theory First, there appear to be many more nonlinear than linear systems (whether naturally occurring or

human-created), and nonlinearity leads to complexity Second, the relationships or connections between parts of systems are just as important as the parts themselves There is, in fact, no meaning without the connections The connections determine the context, and context defines the system Third, there is no "solution " Complexity is about process and evolution, not problems and end-states Fourth, adaptability is the essence of a complex system It has the ability to sense and learn from its environment Reactions to problems are time-sensitive because the system continually evolves – a given reaction will not recur even if the problem is the same, and the problem is never exactly the same And fifth, low-level interactions result in high-level emergent behaviors [66] A squad leader's interactions with the enemy may create the conditions for a complete collapse of enemy defenses, or may cause a friendly attack to stop dead in its tracks

Given these lessons, complexity theory, and a military theory based upon it, cannot be construed as a means of prediction Its utility lies in theory as a means of thinking and understanding As Rosenau points out, "a complexity perspective acknowledges the nonlinearity of both natural and human systems " It can provide a basis to understand and anticipate the general patterns of warfare Complexity theory reminds us we must learn to live with uncertainty because there are inherent limits to the predictability of complex adaptive systems It "can serve as a guide to both comprehending a fragmented world and theorizing within its limits [67]

When we move toward a theory of war based on an understanding of complexity, we are driven toward two virtually unassailable assertions First, "war is fundamentally uncertain " It will not yield to an accumulation of information The interactions among the myriad complex systems involved generate more uncertainty because of the rules of

nonlinear dynamics and because the systems are sensitive to initial conditions Second, "war is fundamentally uncontrollable" Command, therefore, is not a question of control from the top down, it is a question of coping with turbulence and change [68] This assertion of uncertainty and uncontrollability is not to imply that planning or command and control is a futile activity – but it does imply that there are limits to the effectiveness of both – a fact that is well-known by most military leaders.

Given these assertions, a nonlinear theory of war will not result in miraculous victories, radical new doctrines, or unbeatable operations plans – because the nature of nonlinearity will not allow definitive or deterministic conclusions However, "exploring [these ideas] gives us new possibilities for understanding and effective action"[69]

In the interest of exploring new ideas, the following "nonlinear propositions" can serve an initial effort at constructing a foundation for a nonlinear theory of war First, **war is a human endeavor, and humans are complex adaptive systems** Human cognitive limits and sheer physical frailties, coupled with the responsibilities, pressure, and stress of managing and conducting conflict, mean that war will remain a nonlinear activity for the foreseeable future Second, **war exists in a realm of informational uncertainties** Although acquisition of the most precise information possible is the goal, the quest for absolute informational certainties is futile and will lead to a greater vulnerability to surprise, wasted money, and ultimately, lives lost Third, **war is <u>structurally</u> nonlinear** The outcome of combat is fundamentally unpredictable because of unforeseeable events and unknowable initial conditions This unpredictability cannot be overcome [70]

The linear metaphor stands in opposition to the "rules of nature" – for the natural world is a nonlinear world in which complex adaptive systems are the prime actors In an attempt to account for this dichotomy, current military thought makes an artificial separation between the linear and nonlinear elements of war – and has led practitioners to study the art and science of war as two different subjects If the above three propositions are true, that separation cannot stand Thus, in changing the root metaphor, we change the way we analyze and understand war as we know it now, and how we look at it historically And more importantly, we change the way we anticipate the future For in a period of rapid change, it is most important to think holistically, rather than in "stovepipes "[71] And the nonlinear metaphor is a holistic metaphor

It is important to recognize, however, that a change in the root metaphor does not mean "throwing out" everything with even a taint of linearity The change advocated here is much more difficult – keeping the useful linearities, adding the useful nonlinear ideas, and recognizing those that are not useful A nonlinear metaphor also does not mean an end to military planning, or that money spent on information technology is wasted, or that (beginning!) students of the military art should not first be taught the principles of war Again, the change is more difficult and subtle as it involves not a question of whether we do these things, but rather the questions of why we do them and how The metaphor of linearity has been 250 years in the making, changing it is not a trivial nor a short-term process We must take the first steps now, by recognizing the pervasively linear foundation of all our thinking, the weaknesses of the linear metaphor when confronted with the realities of how the world works, and the alternative foundation being exposed for us through the progress in the nonlinear sciences

Andrew Ilachinski of the Center for Naval Analyses has done ground-breaking work on land warfare and complexity, and provides basic guidelines for applying nonlinearity and complexity theory to military thinking, in general He advocates beginning with familiarization throughout the military services and teaching the nonlinear sciences at military schools He further notes that while not all military leaders are born with a Patton's genius, "nonlinear intuition" is vital and all can benefit from practice and instruction in nonlinear analysis And finally, he asserts that an interdisciplinary approach is necessary Tight specialization is the realm of linearists, whereas an open flow of ideas between specialists results in "cross-fertilization" and "out of the box" thinking [72]

War is in every dimension a fundamentally nonlinear activity We have relied on the linear metaphor to be the root of our understanding because we had nothing else The new sciences are now providing the scientific and mathematical means to understand the nonlinear nature of military operations To make full use of this new capability, we must begin a conscious movement toward a new root metaphor – a nonlinear metaphor – and thereby develop a more appropriate foundation for military theory Ultimately, we must strive to be "nonlinear commanders "

> The nonlinear commander conquers whitewater [complexity] by "reading" the turbulence, immersing himself in it, and combining technology, organization, and concept to exploit it [73]

This nonlinear commander-whitewater kayaker rides the waves of chaos, systems dynamics, reaction, and adaptation that are the stuff of complexity instead of trying to e iminate the waves Thus, complexity becomes the natural element of all the dimensions of military operations – as it always has been. Developing a nonlinear theory of war will

be neither an easy nor a short-term task The intent of this paper is to show why we should do so and how changing the root metaphor serves that end When military leaders understand and accept the truth of the quote above, the goal will have been reached

Endnotes

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[20] *Joint Vision 2010* (Washington DC Government Printing Office, n d), pp 13, 16, 28, 15

[21] Ibid , p 1

[22] *Concept for Future Joint Operations* (Ft Monroe VA Joint Warfighting Center, n d), Chapter 5 does a somewhat better job of integrating the nonlinear into the body of the discussion

[23] Ibid , pp 17-22

[24] Ibid , p 64 Culmination is a Clausewitzian concept For an explanation, see Clausewitz, p 528 The first sentence makes it clear that Clausewitz includes both the physical (weapons) and moral (human) dimensions in the concept

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[43] Steven M Rinaldi, "Complexity Theory and Airpower A New Paradigm for Airpower in the 21st Century," in *Complexity, Global Politics, and National Security*, ed David S Alberts and Thomas J Czerwinski (Washington DC National Defense University, 1997), pp 255-6

[44] Ibid , pp 252, 276-9, 284-5, 287-90, 291

[45] This author presents five of these dimensions as existing throughout history, with information and force as newly emerging dimensions resulting from the on-going revolution in military affairs I have added the organizational dimension in order to more thoroughly discuss issues such as command and control Antulio J Echevarria II, "Dynamic Inter-Dimensionality A Revolution in Military Theory," *Joint Force Quarterly* (Spring 1997), pp 31, 32

[46] Ibid , p 31

[47] Jervis, pp 273-4

[48] Echevarria, p 31

[49] Ibid

[50] Eliot A Cohen, "The Mystique of U S Air Power," *Foreign Affairs* (Jan-Feb 1994), pp 113-15

[51] Robert G Spulak, Jr , "Strategic Sufficiency and Long-Range Precision Weapons," *Strategic Review* (Summer 1994), pp 34-7

[52] Thomas J Czerwinski, "Command and Control at the Crossroads," in *Coping With the Bounds Speculations in Nonlinearity in Military Affairs*, Thomas J Czerwinski (Washington DC National Defense University, 1998), p 235

[53] Watts's discussion is centered on proving the continued existence of general friction in modern warfare I regard his description of friction as synonymous with nonlinearity

[54] Watts, pp 63, 65, 68

[55] Ibid , pp 69, 70-1, 75

[56] Ibid , pp 76-7, 78

[57] Clausewitz, p 149

[58] Echevarria, p 32

[59] Cohen, pp 122-3

[60] Spulak, pp 33, 38

[61] Czerwinski, "Command and Control at the Crossroads," pp 235, 246

[62] Clausewitz, p 119

[63] John F Schmitt, "Command and (Out of) Control The Military Implications of Complexity Theory," in *Complexity, Global Politics, and National Security*, ed David S Alberts and Thomas J Czerwinski (Washington DC National Defense University, 1997), pp 231-2

[64] Rinaldi, p 252

[65] Echevarria, p 33

[66] Ilachinski, pp 139-40

[67] Rosenau, pp 89, 91, 92-3, 94, 96

[68] Schmitt, "Command and (Out of) Control," pp 236-8

[69] Jervis, p 274

[70] These propositions are adapted from Watts, p 120, sources of general friction

[71] Michael J Mazarr, "Chaos Theory and U S Military Strategy A "Leapfrog" Strategy for U S Defense Policy," in *Complexity, Global Politics, and National Security*, ed David S Alberts and Thomas J Czerwinski (Washington DC National Defense University, 1997), p 312

[72] Ilachinski, pp 139-40

[73] Czerwinski, "Command and Control at the Crossroads," p 254

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